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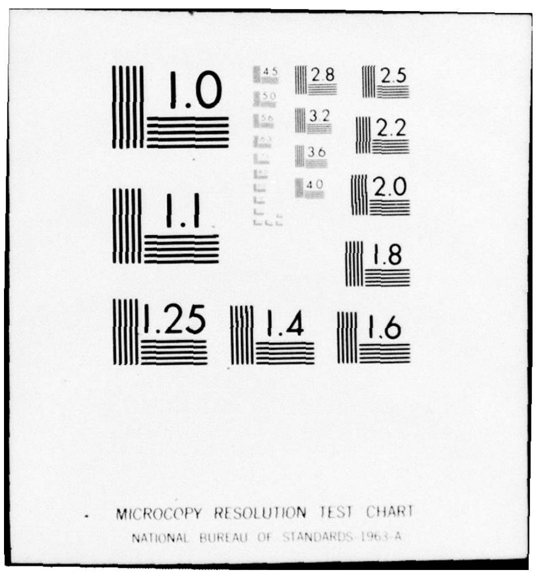
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UNITED STATES AIR FORCE
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USAF ENVIRONMENTAL
TECHNICAL APPLICATIONS CENTER

SCOTT AIR FORCE BASE, ILLINOIS 62225

Report 8413

BUCKLEY DEW-FORMATION STUDY

by

Arnold L. Friend, Capt, USAF

June 1977

REVIEW AND APPROVAL STATEMENT

This report is approved for public release. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Surface weather observations at Buckley Air National Guard Base, Colorado, from 1966 to 1975 provide the basis for estimating the percentage frequency of occurrence of dew on a radome. Consideration is given to the effect of maintaining a minimum temperature of 5°C in the radome and to the moist plume of a nearby cooling tower. Estimates are given of the percentage frequency of occurrence of dewfall by month for three hour time

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groups. The results show most of the dew formation to be caused by the cooling-tower plume intercepting the radome.

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Preface

The USAF Environmental Technical Applications Center (USAFETAC) prepared this report in answer to a request from OL-F, Hq Air Weather Service (AWS) for an estimate of the frequency of occurrence of dew on a radome at Buckley Air National Guard (ANG) Base, Colorado.

This analysis is based on surface weather observations at Buckley ANG Base from 1966 to 1975. Special consideration is given to the effect of maintaining a minimum temperature of 5°C in the radome and to the moist plume of a nearby cooling tower. The natural physical criteria for dewfall are modified to include these special effects. At the desire of the requester, these criteria are applied to achieve the maximum frequency of occurrence since this represents the greatest impact to radome operation.

In the event that this report is incorporated into another report by the requester or any other agency, we request that USAFETAC be given proper credit and be furnished a copy of the new report in all cases where such dissemination is not prohibited.

The USAFETAC prepared this report to answer a specific problem and the report is not expected to have application beyond this problem. Request that further questions on these data be referred to the USAFETAC for consultation and study.

BUCKLEY DEW-FORMATION STUDY

Introduction

The purpose of this report is to estimate the percentage frequency of occurrence of dew on a radome at Buckley Air National Guard (ANG) Base, Colorado. In addition to the usual consideration determining whether or not dew will form, it is necessary to consider the effect of maintaining a minimum temperature of 5°C in the radome and the effect of operating cooling towers in the vicinity of the radome. These cooling towers add moisture to the air at the rate of 1.26×10^3 gm/sec.

Literature Review

A review of the available literature on dew yielded relatively few observational projects and those projects were primarily concerned with the duration and total amount of dew rather than the frequency of occurrence. Of the reports that mention frequency of occurrence, Duvdevani [1] found that dew occurred on 53% of the nights from April to September and on 41% of the nights from October to March for 13 locations in Israel. In Sweden, Huovila [2] observed dew to occur on 47% of the nights from May to October in 1967 and 1968. During the summer of 1958, Lloyd [3] reported that dew occurred on every clear night along streams and in meadows in Idaho. In Iowa, Shaw [5] reported that dew formed on 85% of the no-rain nights during the months of June through September in 1953 and 1954. The vertical variations that appear in these investigations indicate that the intensity varies, but the frequency of occurrence does not vary. It should be noted that most of the above studies were performed for agricultural interests and thus were only concerned with the growing season. This fact probably influenced the frequency of occurrence values since the observations were limited to the first few meters above the ground.

Definition of Dewfall

Dewfall occurs on a nonhygroscopic surface when the temperature of that surface is at or below the dew-point temperature. The conditions most conducive to dewfall are probably best summarized by Monteith [4]. They are: a) clear skies; b) 75% relative humidity measured at standard shelter height at sunset; and c) 1-3 m/sec wind speed throughout the night. Factors which affect the intensity of the dewfall are soil moisture and a recent occurrence of rain or fog. Each of the conditions put forth by Monteith contributes to dewfall in the following manner. Radiative cooling is maximized with clear skies thereby providing very low surface temperatures. A relative humidity of 75% or greater at shelter height is indicative of good moisture content. Finally, low wind speeds inhibit evaporative cooling.

Special Effects

Before investigating the frequency of occurrence of these criteria, it must be determined if and how the two special conditions at Buckley will affect their application. First, the temperature inside the radome is not allowed to fall below 5°C. The effect that this has on the temperature of the outer radome surface must be considered. Since the radome is 33 meters in diameter, the inside temperature is probably not uniform because warm air tends to rise. Assuming that the coldest point within the radome is not allowed to fall below 5°C, it is appropriate to estimate that the outer surface has a minimum temperature of 0°C. This assumption places a lower limit of 0°C on the dew-point temperature used to calculate dewfall on the radome.

The effect of the cooling towers may be estimated by calculating the amount of moisture added to the air by the cooling tower's plume when it reaches the radome. The cooling towers expel water vapor at the rate of 1.26×10^3 gm/sec at a temperature of 301°K with a velocity of 6 m/sec. The distance from cooling tower to radome ranges from 41 meters to 183 meters. To determine the water-vapor concentration when the plume reaches the 36 meter high radome, the Holland Equation (Turner [6]) is used to estimate the effective plume height.

$$\Delta H = \frac{v_s d}{u}\left(1.5 + 2.68 \times 10^{-3}\, p\, \frac{T_s - T_a}{T_s}\, d\right)$$

Where:

ΔH = the rise of the plume above the tower in meters;
v_s = gas exit velocity, 6 m/sec;
d = effective tower diameter, 4.75 m;
u = wind speed, 2 m/sec;
p = atmospheric pressure, 850 mb;
T_s = temperature of vapor leaving the tower, 301°K;
T_a = air temperature, 290°K.

The value of d was estimated and the values of u, p, and T_a were chosen to be representative for Buckley. The Holland Equation, designed for tower diameters of 1.7-4.3 meters and temperatures of 355-475°K, comes the closest to matching the actual cooling-tower conditions. Turner cautions that the Holland Equation frequently underestimates the effective plume height and also says that for stable conditions ΔH should be reduced to 80 or 90% of the calculated value.

Since this study is concerned with dewfall, the conditions would normally be neutral or stable. The calculated ΔH of 27 meters was not reduced because the effect of the stable conditions should be balanced by the tendency for ΔH to be underestimated. Turner also cautions that since plume rise occurs over some distance downwind, ΔH should not be applied within the first few hundred meters from the source. Based on the above values, the effective plume height (cooling-tower height plus plume rise) is 31 meters.

Table 1 shows the decrease in concentration as a function of downwind distance at a height of 27 meters above the ground. These concentrations were obtained by solving Turner's [6] Equation 3.1. Since the effective plume height is 31 meters and the radome height is 36 meters, the center of the plume would intersect the radome if the wind is from the proper direction. When this occurs, the mixing ratio of the plume (which has a one-to-one correspondence to the water-vapor concentration for the conditions at Buckley) will effect dew formation. If the plume is mixed with the surrounding air, the concentration in the plume must be added to the ambient concentration to obtain the total vapor content. However, with the radome being less than 200 meters from the plume's source, there is very little mixing, particularly under stable conditions. In this situation, when the plume concentration exceeds the ambient concentration, the plume concentration will determine whether or not dewfall occurs. The criteria of 75% relative humidity necessary for dewfall must be met either by the ambient air or by the plume if the plume intersects a radome. The arrangement of cooling towers and radomes at Buckley is such that winds from the northwest through northeast to southeast will cause the plume to intersect at least one radome.

Results

Ten years (1966-1975) of surface weather observations for Buckley ANG Base, Colorado were used to estimate the percentage frequency of occurrence of dewfall by month. Tables 2 and 3 contain these estimates for three hour time periods from late afternoon to early morning plus the total for the six time periods. Dewfall was considered to occur for an observation which satisfied the following conditions: sky not overcast; wind speed less than or equal to 3 m/sec; temperature above 0°C; and ambient relative humidity greater than 75% or plume relative humidity greater than 75% when the wind direction is between 315-135 degrees.

The percentage frequency of occurrence of observations satisfying these conditions is given in Table 2. The noticeable decrease during the winter months can be attributed to the 0°C criteria. To evaluate the influence of the cooling-tower plume on these estimates, Table 3 was prepared based only on the plume effects. The occurrence of dewfall is dominated by the cooling-tower plume.

Summary

The results show that dew can be expected to occur more frequently in summer than in winter. Furthermore, the occurrence of dew on a radome at Buckley ANG Base is very dependent on the effect of the cooling-tower plume. Due to the lack of observations for the cooling-tower plume, many assumptions and approximations were required to complete this study. If observations become available, these assumptions and approximations should be reviewed for possible revision.

References

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[2] Huovila, S., 1968: "On the Amount of Dew in Finland." Geophysica, Vol. 10, No. 113, pp. 75-80.

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[5] Shaw, R. H., 1955: "Research directed toward the observation of dew deposition on various types of cover." Iowa State College, Final report, 60 pp.

[6] Turner, D. B., 1969: Workbook of Atmospheric Dispersion Estimates, U. S. Dept. of Health, Education and Welfare, Public Health Service Pub., No. 999-AP-25, 84 pp.

Table 1. Water-Vapor Concentration (gm/kg) as Function of Distance from the Cooling-Tower.

Distance (m)	100	125	180	300
Concentration (gm/kg)	2.40	2.63	2.19	1.25

Table 2. Estimated Total Percentage Frequency of Occurrence of Dewfall by Month on a Radome at Buckley ANG Base.

Period of Record: 1966-1975

Month	Total Observations	Time Periods (GMT)						
		00-02	03-05	06-08	09-11	12-14	15-17	Total
1	7340	1.47	.65	.48	.45	.33	.52	3.90
2	6691	2.76	1.03	.52	.28	.33	.97	5.89
3	7371	3.12	1.89	.95	.95	.72	1.55	9.18
4	7117	3.82	2.78	2.28	2.56	2.22	3.15	16.81
5	7488	4.22	3.63	3.35	3.51	2.90	3.86	21.47
6	7292	4.72	4.18	3.87	3.94	3.43	4.42	24.56
7	7546	4.47	3.46	3.38	4.29	3.49	4.94	24.03
8	7466	4.65	2.92	2.46	3.35	3.09	4.41	20.88
9	7297	5.45	3.47	3.28	3.49	3.52	3.66	22.87
10	7377	5.40	2.82	2.20	2.17	2.14	2.74	17.47
11	7090	3.07	1.58	.99	.92	.66	1.30	8.52
12	7247	1.79	.68	.57	.36	.29	.59	4.28

Table 3. Estimated Cooling-Tower Induced Percentage Frequency of Occurrence of Dewfall by Month on a Radome at Buckley ANG Base.

Period of Record: 1966-1975

Month	Total Observations	Time Periods (GMT)						
		00-02	03-05	06-08	09-11	12-14	15-17	Total
1	7340	1.44	.61	.45	.45	.31	.49	3.75
2	6691	2.76	1.02	.52	.28	.33	.94	5.85
3	7371	3.12	1.76	.83	.87	.65	1.42	8.65
4	7117	3.77	2.46	1.53	1.33	1.28	2.88	13.25
5	7488	4.07	3.11	2.18	1.67	1.79	3.71	16.53
6	7292	4.61	3.61	2.45	1.96	1.95	4.25	18.83
7	7546	4.17	2.86	2.09	1.93	1.66	4.68	17.39
8	7466	4.58	2.40	1.38	1.26	1.23	4.31	15.16
9	7297	5.28	2.77	1.95	1.95	1.92	3.40	17.27
10	7377	5.10	2.18	1.46	1.23	1.36	2.36	13.69
11	7090	2.81	1.30	.83	.66	.51	1.10	7.21
12	7247	1.79	.65	.54	.33	.29	.58	4.18